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TRANSMITTING ARRAYS FOR LOW-POWER RELAY STATIONS: arrays of u.h.f. log-periodic aerials

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TRANSMITTING ARRAYS FOR LOW-POWER RELAY STATIONS: ARRAYS OF UHF LOG-PERIODIC AERIALS

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Summary

Log-periodic aerials are considered for use as transmitting arrays at low-power u.h.f. relay stations. The movement of the aerials' phase-centre with frequency requires careful positioning of aerials in an array to preserve radiation pattern bandwidth. The aerials are mounted on arms up to 0·7 m long fixed to a cantilever pole by friction clamps. Measured horizontal and vertical radiation patterns of typical aerial installations are presented and from these their gain is computed. The reflection coefficient of an aerial array should present no problems with modern transposers. The radiation pattern performance can be predicted satisfactorily for planning purposes.

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1. Introduction

The directional aerial requirements of low-power u.h.f. relay stations are at present largely satisfied by the vertically-polarised 2λ printed panel aerial.[1] The use of the ruggedised log-periodic aerial[2] in similar circumstances is now being considered for the smaller relay stations to reduce costs. It is likely that the unit cost of a log-periodic aerial could be low because of its versatility; it is wideband and suitable for both transmission and reception. The lower wind-loading pressure exerted on the mast is likely to lead to a cheaper pole and support structure.

Log-peridoic aerials to the BBC designs are not yet commercially available but some experience of their use in service is being gained from a simple array of four stacked prototype aerials at Ogmore Vale. The pre-installation tests made on that aerial are described in a recent report.[3]

This report describes the way in which log-periodic aerials can be arrayed to achieve the most suitable and useful radiation patterns.

2. Array design

The arrangement of aerials which is likely to be most common is that of a single aerial or a number of tiers of single aerials stacked vertically to increase directivity. The horizontal radiation pattern bandwidth varies slightly with frequency between 68° and 74° at the 3 dB points. If a broader pattern is desired two aerials pointing on different bearings can be used for each tier, the included angle being chosen to suit the application. Beam-tilting to redirect the regions of maximum radiation to some small angle below the horizontal and gap-filling of the primary nulls in the vertical radiation pattern can be achieved by appropriate phasing of the distribution feeders.

When designing aerial arrays an accurate knowledge of the electrical separation between them is important for computing the total radiation pattern. The reference point associated with an aerial and which is used for this purpose is the 'phase-centre' of the aerial. The concept of a phase-centre and its particular application to a log-periodic aerial has been discussed in another report.[4] Radiation from a log-periodic aerial is confined to a small group of dipole elements at any one frequency. As the frequency changes this 'active region' moves up and down the axis of the aerial. It is understandable, therefore, that the phase-centre is also dependent on the frequency of operation. The location of the phase-centre measured from the front of the short-circuit plate of the aerial for different frequencies is given in Table 1 for reference.

TABLE 1

Phase-Centre Position of a Log-Periodic Aerial

f (MHz)	Distance of phase-centre from front of short circuit plate (mm)
450	365
500	460
550	548
600	618
650	678
700	729
750	775
800	812
850	847
900	875

In the case of a single aerial per tier there is no special problem with the movement of the phase-centre because the separation between individual phase-centres remains the same. When there are two aerials per tier the aerials must be positioned very carefully to avoid a large variation in separation of phase-centres. It is not possible to achieve a wide pattern bandwidth if the aerials are mounted with their back plates against the mast and pointing outwards.

An acceptable pattern bandwidth is achieved by crossing over the two aerials in a tier at a specified point along their axis. It is found that two cross-over points are sufficient to cover the Bands IV and V, one for each band. These were found by experiment and are.

Band IV: 250 mm from front of short-circuit plate
Band V : 550 mm from front of short-circuit plate

These arrangements allow the phase-centre separation to vary between about 0·25λ and 1·5λ. At wider separations than this the nulls in the forward lobe of the radiation patterns deepen and make the horizontal radiation pattern unsuitable for transmitter purposes.

The two aerials need to be staggered in height to effect the cross-over without the aerials interfering with one another. It is convenient that when the aerials are tiered in this fashion there is space in between two tiers for the other aerial of a tier pointing in another direction.

The aerials of the array are fed from conventional splitter transformers in the same way as for arrays of panel aerials. At smaller stations it may be appropriate to use the printed circuit type of splitter transformer.[5]

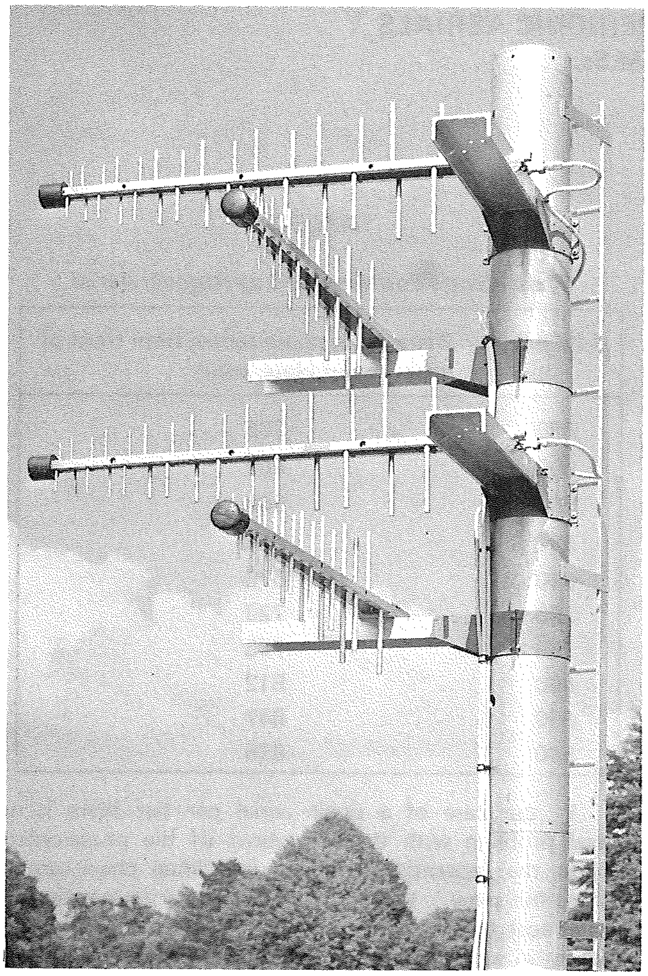

Fig. 1 - Band IV arrangement of two tiers of log-periodic aerials set at 90°

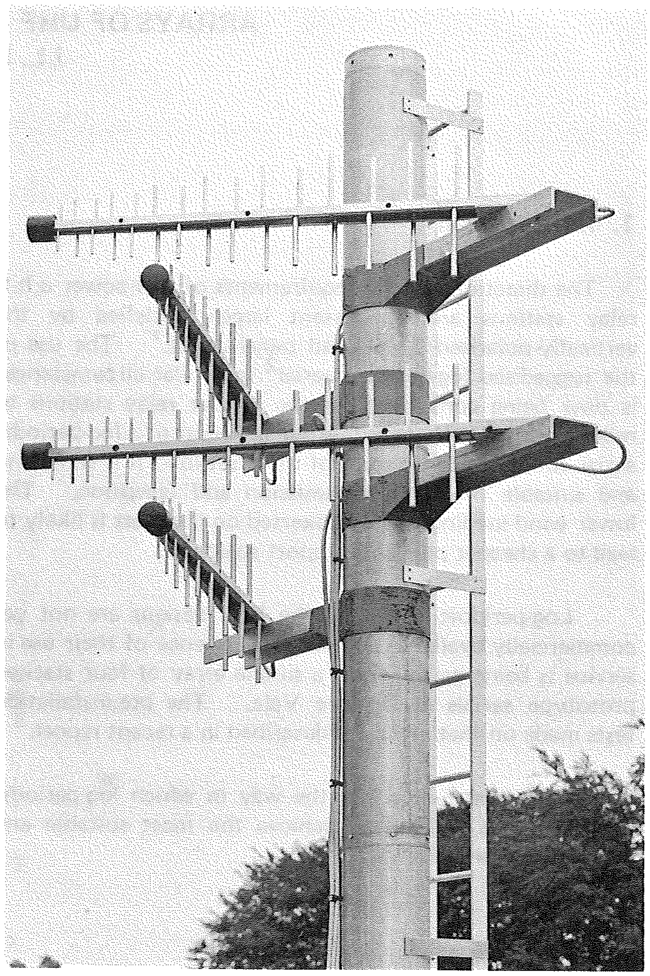

Fig. 2 - Band V arrangement of two tiers of log-periodic aerials set at 90°

3. Mechanical arrangement

The Band IV and Band V versions of arrangements with two tiers of two aerials per tier set at 90° are shown in Figs. 1 and 2 respectively. Arrays of log-periodic aerials are intended to be mounted on a standard 6 5/8 in. cantilever pole in the same way as panels. Clamping plates bolt over and sandwich the back-plate of each aerial to a stiff arm protruding from a friction clamp fixed to the pole. The arms can be short if there is only a single aerial per tier but must be longer for the crossed arrangements. The arm lengths are approximately 0·45 m for Band IV and 0·7 m for Band V. (The arms shown in Fig. 1 would be shorter in practice.)

In the Band IV arrangement the support arms are set at right angles to keep the aerials further away from the pole which can otherwise cause interference to the radiation pattern. In the Band V arrangement the support arms are fixed in line with one another.

4. Measured results

4.1. Horizontal radiation patterns

The measured horizontal radiation patterns, (h.r.p.'s) for the Band IV and Band V versions of two arrays with two aerials per tier are shown in Figs. 3 – 6. Typical included angles of 90° and 120° have been chosen for the examples and measurements are made at three frequencies in each band.

The general pattern shape is somewhat similar to those of the panel aerials but there are two notable differences. In the case of two aerials set at 90°, the patterns are almost cardioidal at the lower end of the bands but with a more rapid fall-off of the side-lobes. For two aerials set at 120°, the formation of the forward lobe is quite different.

There is very little radiation in the backward direction: the regions where a good quality of service cannot be guaranteed are marked on the figures.

Some assymmetry in the h.r.p. is expected at angles of declination below the horizontal because of the way the two aerials in each tier are staggered slightly in height. This peculiarity is apparent on the contour radiation pattern plots where both horizontal and vertical radiation pattern information is presented (see Figs. 13 – 16).

4.2. Vertical radiation patterns

The measured vertical radiation patterns, (v.r.p.'s) of

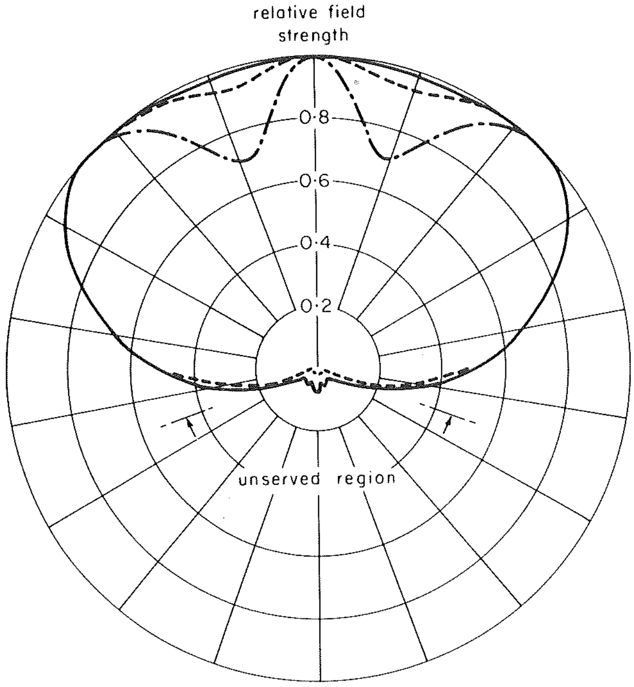

Fig. 3 - Measured horizontal radiation pattern: 2 aerials set at 90°, Band IV

——— 470 MHz ----- 530 MHz —·—·— 600 MHz

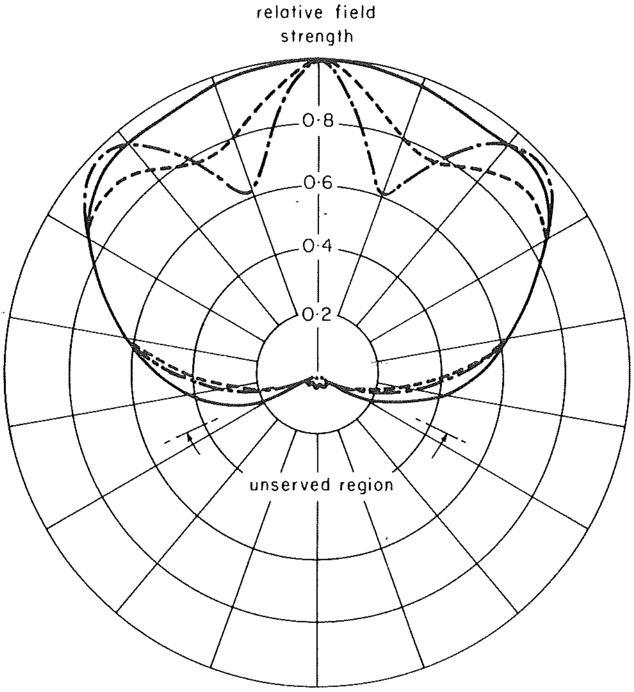

Fig. 4 - Measured horizontal radiation pattern: 2 aerials set at 90°, Band V

——— 600 MHz ----- 720 MHz —·—·— 860 MHz

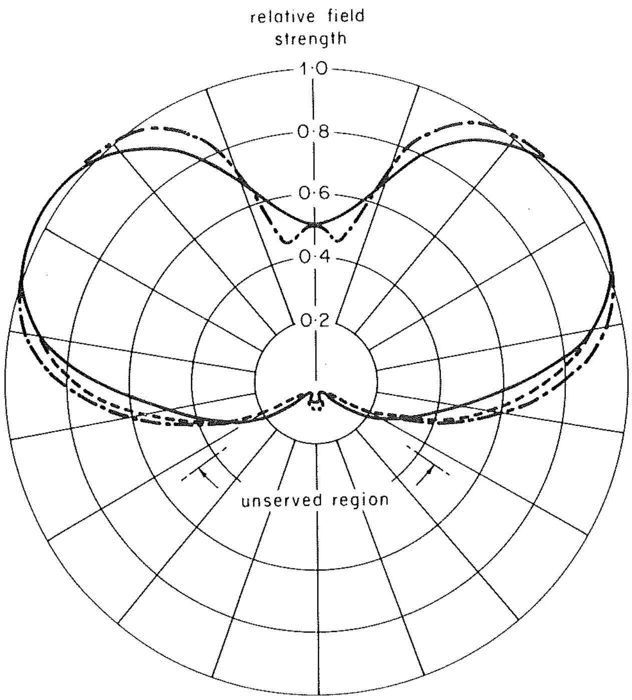

Fig. 5 - Measured horizontal radiation pattern: 2 aerials set at 120°, Band IV

——— 470 MHz ----- 720 MHz —·—·— 860 MHZ

600

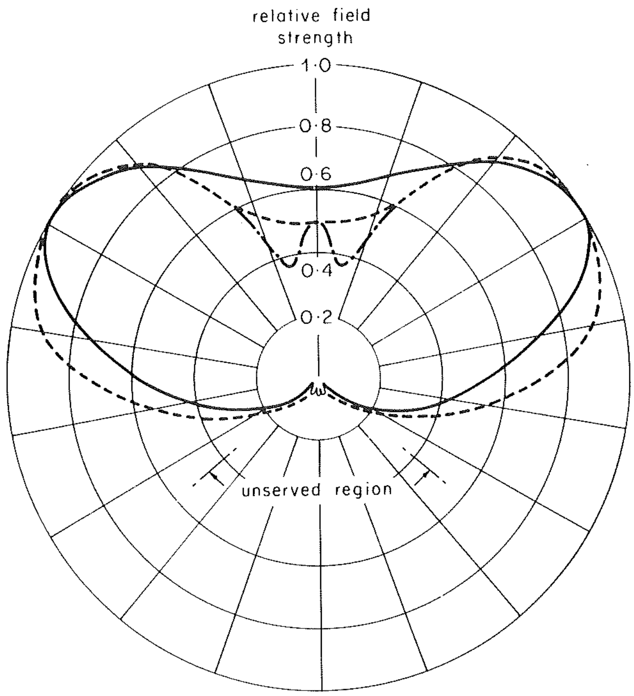

Fig. 6 - Measured horizontal radiation pattern: 2 aerials set at 120°, Band V

——— 600 MHz ----- 720 MHz —·—·— 860 MHz

2 and 4 tiers of aerials at the h.r.p. maxima are shown in Figs. 7 and 8 respectively. The vertical separation of the aerials is chosen to maximise the gain over the band. Because it is relatively easy to position aerials at different heights by adjustment of friction clamps, two settings are chosen to cover Band V and achieve a higher overall gain. The vertical separations of 2 and 4 tiers of aerials are given in Table 2.

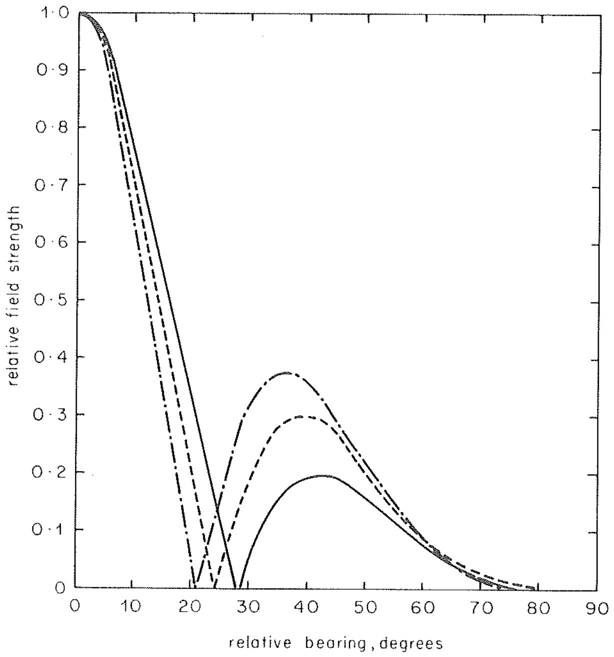

Fig. 7 - Measured vertical radiation pattern: 2 tiers of a single aerial

	Band IV	Lower Band V	Upper Band V	
———	450	600	720	Frequency (MHz)
- - - -	530	720	825	
— — —	600			

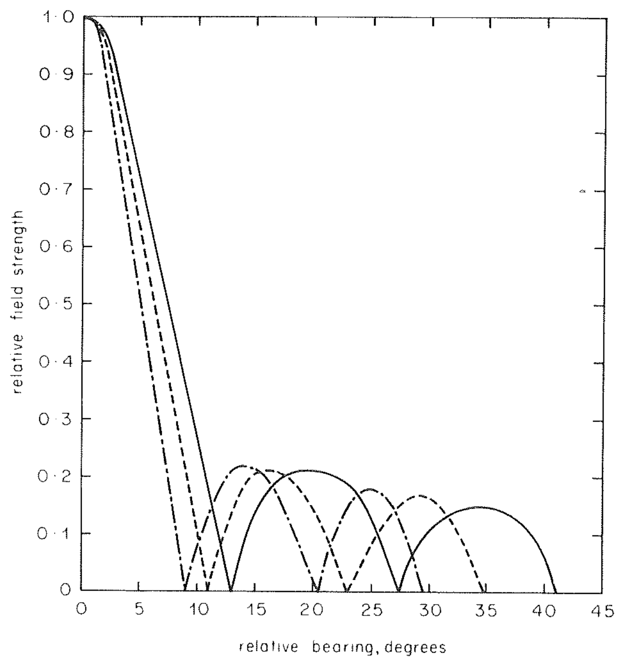

Fig. 8 - Measured vertical radiation pattern: 4 tiers of a single aerial

	Band IV	Lower Band V	Upper Band V	
———	450	600	720	Frequency (MHz)
- - - -	530	660	780	
— — —	600	720	860	

TABLE 2

Vertical Aerial Separation for Multi-Tiers

	Vertical Separation (mm)	
	2 Tiers	4 Tiers
Band IV	680	750
Lower Band V	520	580
Upper Band V	440	500

In special cases there may be a requirement for a greater vertical aperture in which case the vertical separation would have to be determined.

4.3. Aerial gain

The aerial gain of some typical arrangements of log-periodic aerials are shown in Tables 3 to 5. The gain is calculated by integrating the measured v.r.p. and making an allowance for the maximum-mean radiation of the horizontal radiation pattern. The values quoted are relative to a half-wave dipole and include the losses associated with the internal feeder of the log-periodic aerial and with the necessary distribution transformers and distribution feeders.

TABLE 3

Gain of Single Tier of Aerials (dB)

Channel Number	21	33	53	65
Single aerial	8·1	8·2	8·1	7·7
2 aerials, set at 90°	4·7	5·3	5·2	5·2
2 aerials, set at 120°	4·8	5·0	5·1	

TABLE 4

Gain of Two Tiers of Aerials (dB)

Channel Number	21	33	53	65
Single Aerial/Tier	10·9	11·0	10·7	10·5
2 Aerials/Tier, set at 90°	7·5	8·0	7·9	8·0
2 Aerials/Tier, set at 120°	7·6	7·8	7·8	

TABLE 5

Gain of Four Tiers of Aerials (dB)

Channel Number	21	33	53	65
Single Aerial/Tier	13·8	14·0	13·8	13·6
2 Aerials/Tier, set at 90°	10·4	11·1	11·0	11·1
2 Aerials/Tier, set at 120°	10·5	10·9	10·9	

Gap-filling of the v.r.p. and beam tilting of the main beam will tend to reduce these figures.

4.4. Impedance

At a typical u.h.f. low power relay station, where there may be 150 feet of feeder between transposer and aerial, the relative amplitude of a radiated delayed signal resulting from the mismatch at the aerial should be kept below −34 dB.[6] Assuming that the reflection loss at the transposer is unlikely to be less than 12 dB, the maximum reflection loss which can be tolerated at the aerial is

18% in Band IV
22% in Band V

The maximum reflection coefficient of a single log-periodic aerial is 11%.[2] This may increase to 13% in heavy rain. When a distribution transformer and feeders are taken into account, the maximum reflection coefficient of a log-periodic aerial array will rise above this. It is not likely, however, to exceed the figures arrived at above.

5. Computed results

For service planning purposes it is convenient to have a means of predicting the radiation pattern behaviour of a proposed transmitting aerial array. A computer program has been used for some time to provide this information for arrays of panel aerials, and it would appear possible to do the same for arrays of log-periodic aerials.

The data required by the computer are the frequency of operation, the locations of the individual aerials, their direction of fire and the complex radiation pattern of a single aerial in at least two planes. The complex radiation pattern of a log-periodic aerial is variable in the phase term because of the phase-centre movement with frequency. If the complex pattern data were used to produce an array pattern, a different set of pattern data would be required for each array. This is very inconvenient.

If it is assumed that the phase-centre of the log-periodic aerial is valid for all angles of azimuth, the aerial can be thought of as one with a constant phase pattern at each frequency of operation, based on its phase-centre position. This assumption is possible in practice because the radiation level outside the main beam region is more than −20 dB below the maximum radiation. Only the radiation pattern amplitude of a single aerial is now required and this is independent of frequency. The program can be adapted to avoid the need of providing this data for each run. The aerial location data, however, now includes a factor dependent on frequency because apart from the physical position of an aerial the relative position of its phase-centre must be considered at each frequency. This method of working appears to be the most efficient way of overcoming the problem of a phase-centre moving with frequency.

The assumptions associated with this approach and the method of computation may be summarised:—

(i) The phase-centre concept is valid for a log-periodic aerial and may be assumed to hold for all angles of azimuth.

(ii) The back- and side-lobe radiation is very low outside the main beam region.

(iii) The h.r.p. of a single aerial remains substantially constant throughout the u.h.f. Bands IV and V.

(iv) The pole and support structure do not influence the radiation pattern unduly.

The computing method has been tested by producing the h.r.p.'s of typical arrays, set at 90° and 120° respectively at a number of frequencies. In general there is a very close resemblance between the computed and measured results. Figs. 9 – 12 show the results for an array of two aerials set at 90° computed at the extreme frequencies in Band IV and Band V. Also shown are the envelopes of measured results taken from several sets of measurements. The biggest differences between computed and measured results can be estimated for the region of the patterns down to −10 dB relative to the maximum radiation level. They are

±1·5 dB in Band IV
±2·0 dB in Band V

This should be sufficiently accurate for planning purposes. There are three main areas of disparity which are directly related to the foregoing assumptions.

(i) At the lower end of both Bands (refer to Figs. 9 and 11) the measured pattern at the side of the main-lobe region tends to be broader than the computed result. This can be ascribed to the scattering which takes place from that portion of the active region of an aerial which lies behind the point at which the two aerials cross. For the rest of the Band the active region moves forward until it is entirely in front of the cross-over point.

(ii) The h.r.p. of a log-periodic aerial broadens slightly towards the upper end of Band V. Referring to Fig. 12 it is seen that the effect of this is to make the null formed in the forward lobe shallower and occur at a narrower angle in the computed result compared with the measured result. The difference is, however, small.

(iii) In Band V the phase-centre of the log-periodic aerial is more sensitive to the angle of azimuth and this makes the precise shape of the measured pattern slightly erratic but again the differences are very small.

Examples of the computed contour plots, embodying the horizontal and vertical radiation pattern information are shown in Figs. 13 – 16 for 2 tiers of log-periodic aerials set at 90°. The frequencies at which the computations have been made are the same as those chosen for Figs. 9 – 12. The slight assymmetry due to the vertical staggering of aerials in a tier is apparent.

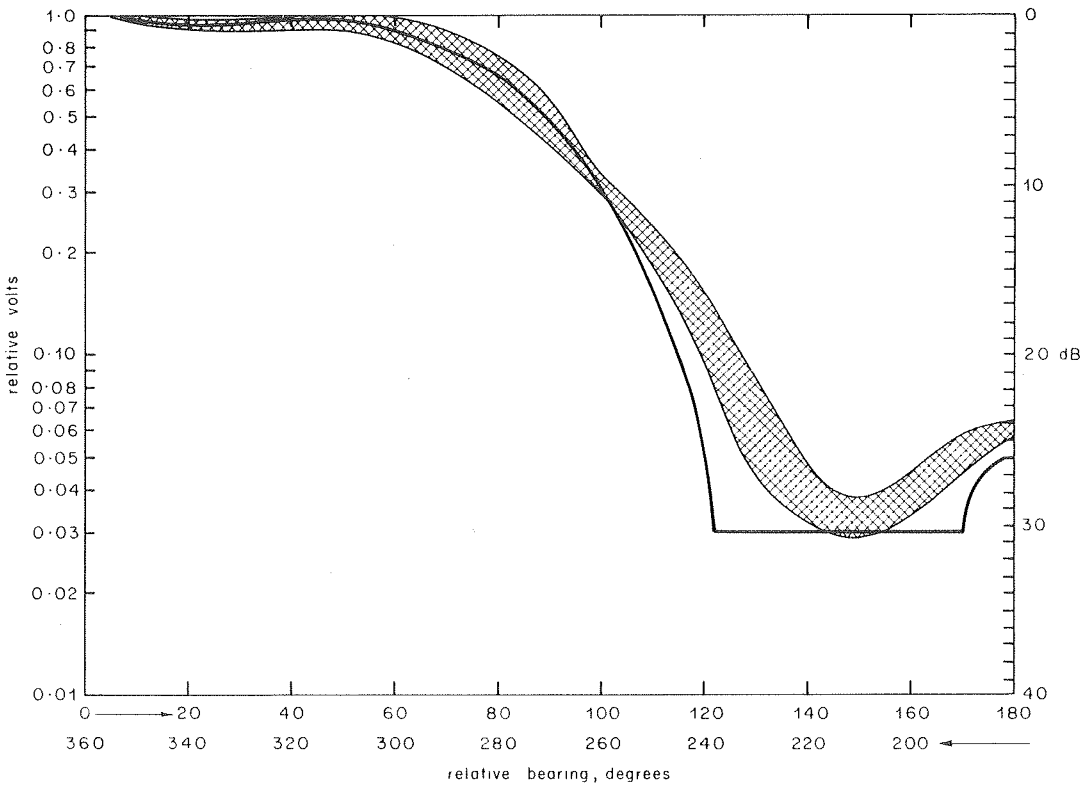

Fig. 9 - Computed and measured horizontal radiation pattern, 2 aerials set at 90°, 470 MHz

Computed result   Measured result

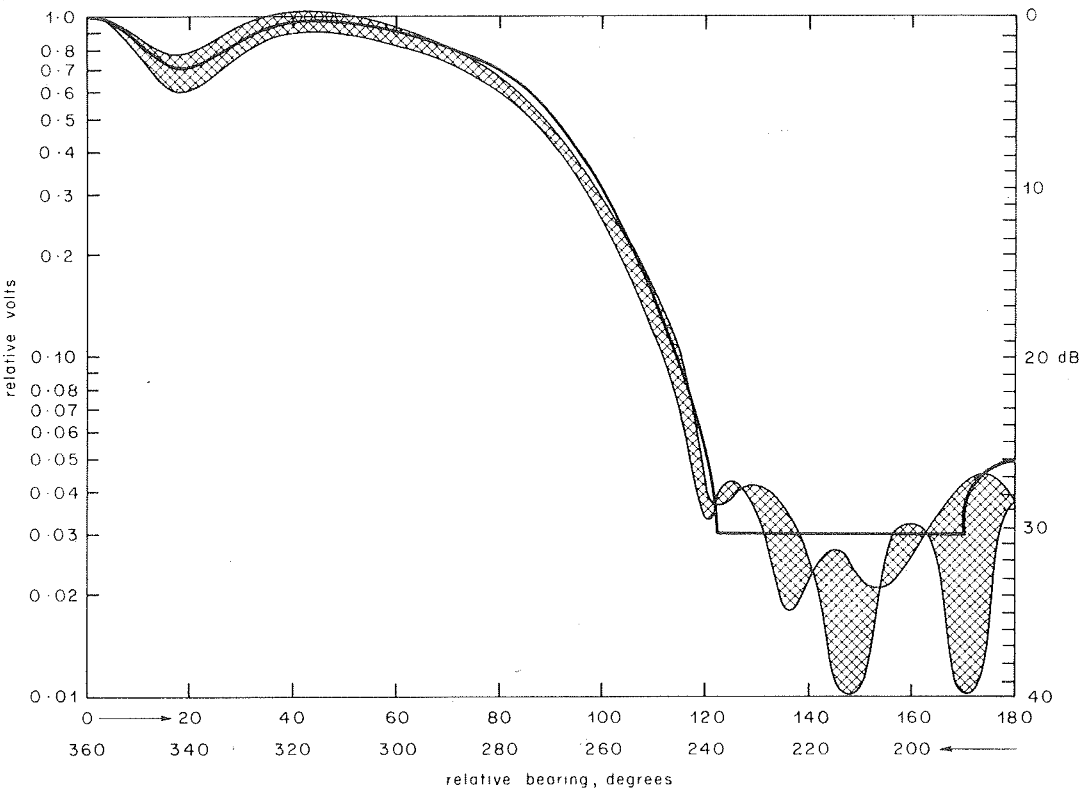

Fig. 10 - Computed and measured horizontal radiation pattern, 2 aerials set at 90°, 600 MHz, Band IV arrangement

Computed result   Measured result

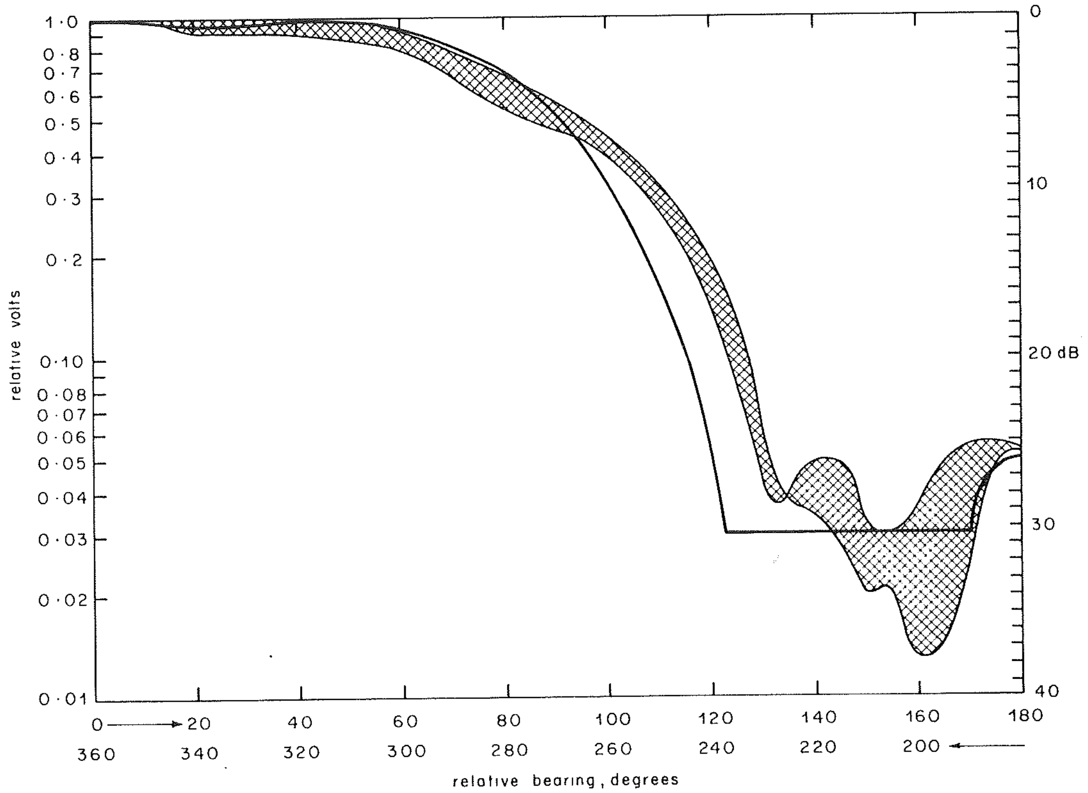

Fig. 11 - Computed and measured horizontal radiation pattern, 2 aerials set at 90°, 600 MHz, Band V arrangement

——— Computed result Measured result

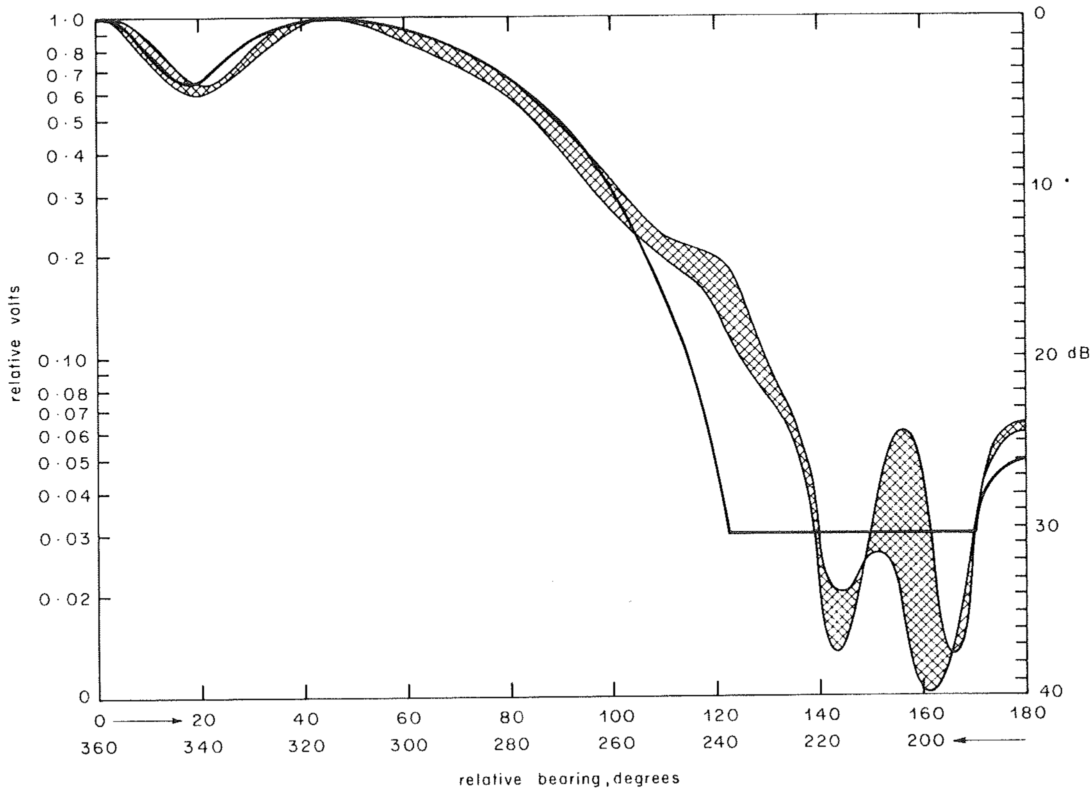

Fig. 12 - Computed and measured horizontal radiation pattern, 2 aerials set at 90°, 860 MHz

——— Computed result Measured result

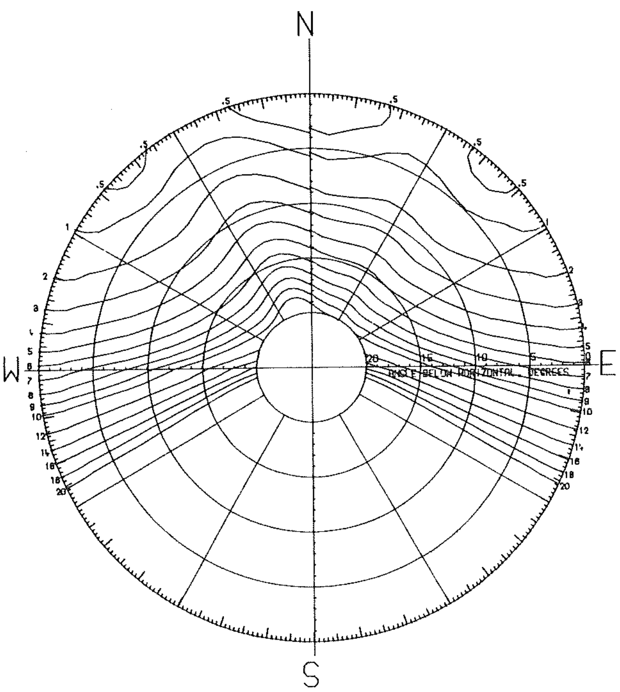

Fig. 13 - Channel 21

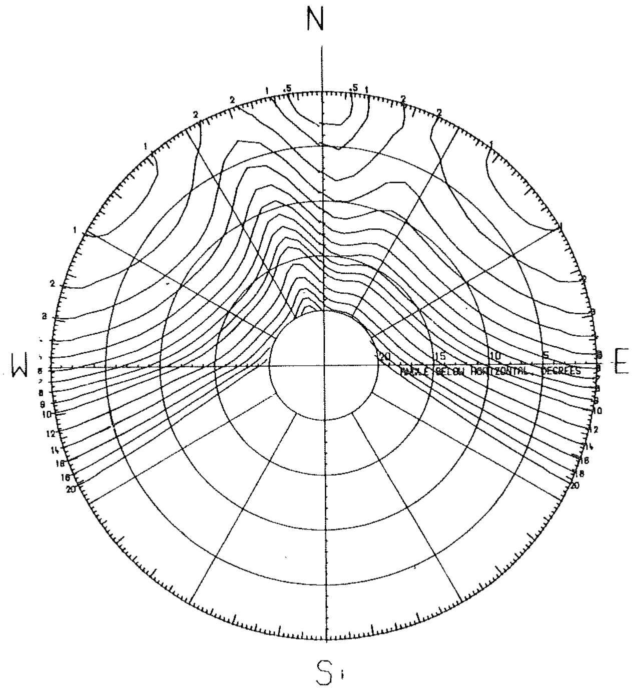

Fig. 14 - Channel 33

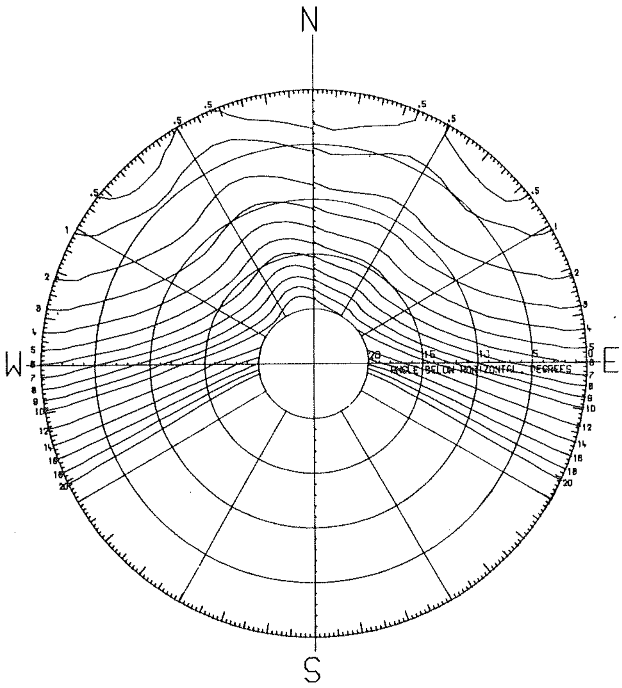

Fig. 15 - Channel 39

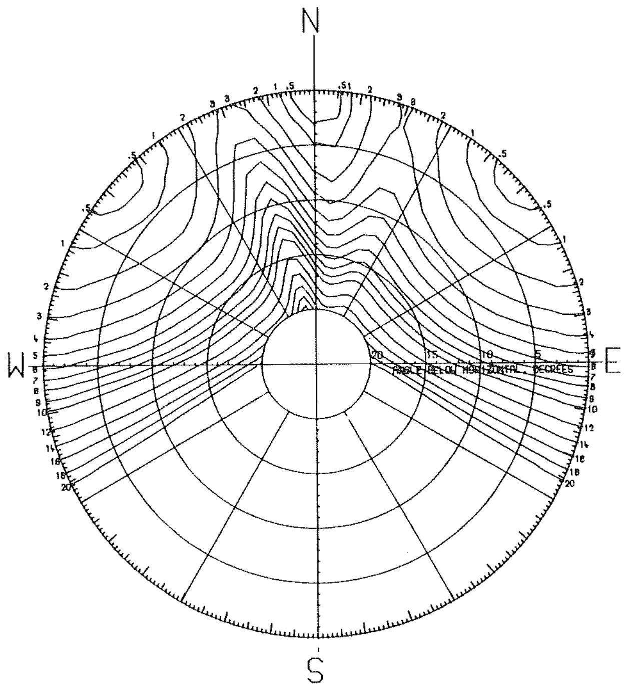

Fig. 16 - Channel 68

Figs. 13 – 16. Computed contour radiation pattern plots: 2 tiers of 2 aerials set at 90°

6. Conclusions

It has been shown that log-periodic aerials can be arrayed successfully to produce suitable radiation patterns for low-power relay stations. The computed contour plots appear to give a satisfactory indication of the radiation pattern performance for planning purposes.

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